DOCUMENT RESUME

ED 263 016 SE 046 241

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TITLE Self-Regulation While Practicing Addition Facts on the Microcomputer.
PUB DATE 79
NOTE 50p.; Paper presented at the Annual Meeting of the North American Branch of the International Group for the Psychology of Mathematics Education (1st, Evanston, IL, September 5-8, 1979).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Addition; *Cognitive Processes; *Computer Oriented Programs; *Elementary School Mathematics; Grade 1; Mathematics Education; Microcomputers; Primary Education; *Problem Solving
IDENTIFIERS *Self Regulation

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The purpose of the study was to survey self-regulation while responding to the addition facts. First graders' performance on microcomputer practice exercises was observed and recorded. Subjects could choose an analytic mode of operation using a symbolic or a finger strategy; or, they could choose a geometric mode of operation using a pictorial or manipulative strategy. An analysis of protocol data indicated that six subjects progressed from the analytic to the geometric modes of operation as problems increased in difficulty; the remaining seven subjects consistently chose either the analytic or harmonic modes of operation (combination of the analytic and geometric). All subjects were highly successful. Eleven of the 13 subjects scored at least 91% correct on each of the four levels of difficulty. The remaining two subjects scored at least 78% correct on each level. (Author)

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# Self-Regulation While Practicing Addition Facts on the Microcomputer

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Running Head: Self-Regulation

Paper presented at the First Annual Meeting of the North American Branch of the International Group For the Psychology of Mathematics Education. Northwestern University, September 5-8, 1979.

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# Self-Regulation While Practicing Addition Facts on the Microcomputer

The purpose of this study was to survey the tendency to self-regulate responding to addition facts on microcomputer practice exercises. First graders' performance was observed and recorded. Subjects could choose symbolic, finger, pictorial, or manipulative strategies.

## Related Literature

Numerous questions have been raised (Friedman, 1978; Kieren, 1971) concerning various aspects of the action-image-symbol sequence (Bruner, 1963, 1966, 1973; Dienes, 1960; Flavell, 1963). Some minds, it is suggested (Krutetskii, 1976), tend to interpret the environment analytically through verbal and logical systems, others do so geometrically through visual imagery, and still others interpret the world harmonically through a combination of the first two approaches. This position appears to suggest that the learning of mathematics does not strictly occur through stages of development interrelated with the action-image-symbol sequence.

Some questions that follow are: How should mathematics be taught? For example, should the models of representation be chosen according to the learner's stage of cognitive development? Should the use of models be determined according to the type of students receiving the instruction? Or, does the learner self-regulate the use of these models? Since research results so far do not overwhelmingly support the effectiveness of one model over another, the final question raised above appears to be viable.

Piaget (Inhelder, Sinclair, & Bovet, 1974) made us aware that organisms are equipped with biological self-regulatory mechanisms or structures which can

adapt to new stimuli. He asked if there were "similar mechanisms at work in establishment of cognitive structures" (p. 16). A related question to ask is: are there self-regulatory mechanisms behavioristic by nature and do they in turn govern the type of thinking an individual does most instinctively?

The present study focused on the very young student of arithmetic. The response to addition facts appeared to be a viable area for investigating apparent tendencies toward self-regulation. Addition is a routine part of the arithmetic class and has the potential for revealing any ideosyncratic learning behaviors.

Even when children are taught addition through a specific algorithmic manipulation of blocks, they tend to return to their finger algorithms (Groen and Resnick, 1977). Ginsberg (1977) suggests that using invented finger counting methods is a higher means to adding and subtracting. He found that, "many young children do not add or substract by remembering number facts . . . they calculate by means of invented counting methods, often involving use of the fingers" (p. 94). Children would count more frequently than not if it were permitted or emphasized instead of discouraged. In fact, many of the informal strategies are more sophisticated and demonstrate more insight than formal procedures that are a part of instruction (Carpenter, Hiebert, and Moser, Note 2).

Hendrickson (1979) found that first graders tend to impose their own interpretation which is different from that initially presented during instruction. The given problem becomes "their" problem. Thornton (1978, 1979), however, stated that her research results implied that addition thinking strategies should be presented before drill. But Cifarelli and Wheatley (1979) argued against the validity of this implication, since it was based on a study in

which the treatment included drill with the presentation of thinking strategies. Thus, the results and implications of the Thornton study are left in abeyance.

The specific questions addressed by the present study were: (1) Do children regulate themselves into one of three modes of operation - the geometric, the harmonic, or the analytic - while practicing the basic addition facts? (2) Do those who initially prefer one mode of operation eventually choose more concrete strategies as material increases in difficulty? (3) Can children demonstrate success when they choose their own strategy?

## Methodology And Procedures

A clinical methodology was used. The performance of first graders on microcomputer exercises was observed and recorded to detect which mode of operation was used. Subjects chose an analytic mode of operation if they used a symbolic or a finger strategy; they chose a geometric mode of operation if they used a pictorial or a manipulative strategy. These strategies are described below. Each strategy was followed by pressing a numerical response on the keyboard by the subject.

| | Mode of Operation | Strategy | Description |
|---|---|---|---|
| Harmonic | Analytic | Symbolic | Mental calculation |
| | | Fingers | Mental calculation assisted by fingers |
| | Geometric | Pictorial | Use of slide rule picture on video monitor |
| | | Manipulative | Use of manipulative slide rule with movable blocks |

Thirteen first graders ranging in age from 6 years 8 months to 7 years 6 months, with a median age of 7 years 3 months, were the subjects of the study. They attended a successfully integrated middle class Atlanta school. The interviews took place in the eighth month of their first grade year. By this time students knew the concept of addition so the study was able to pick up strategy preferences.

An interactive program written in Level II BASIC for the TRS-80 microcomputer was designed to generate the basic addition facts where all the facts, excluding those having zero as an addend, were presented horizontally one at a time in random order on a 12-inch video monitor.

Initially, the program printed a greeting and asked for the student's name which was used at various points during execution of the exercise. The student was given immediate feedback on the accuracy of each response and on the total performance on each of four levels of difficulty. These levels were Level 1 facts having sums to 6; Level 2 facts having sums to 10 not including those to Level 1; Level 3 facts having sums to 14 not included in Levels 1 or 2; and Level 4 facts having sums to 18 not included in Levels 1,2, or 3. These levels were determined for this study through the findings of Suppes and Morningstar (1972), Suydam and Weaver (1976), and Thornton (1978).

Each time a fact was randomly generated, the subject could choose to respond by using a mental process with or without finger assistance, by using a picture of a slide rule generated on the video monitor after pushing P on the keyboard, or by using a concrete manipulative slide rule requiring the placement of small blocks representing addends.

The fact 2+3 = ?, for example, would be done on the manipulative slide rule by placing two blocks aligned with the 1 and 2, respectively, on the stationary part of the horizontal slide rule grid. Three more blocks would be

placed on the unnumbered movable horizontal grid below the numbered grid. This lower grid, then, would be slid to the right until the three blocks on it would be aligned with the 3,4, and 5, respectively. Five would be the final numeral having a block aligned and would be the sum of 2+3. The pictorial version of this on the video monitor would show the lower blocks (the second addend) already slid to the right.

Each subject started on Level 1 in the beginning of the first session. At the beginning of each session following, each subject started at the next more difficult level than the one last mastered. A subject reached level mastery if 80% of the problems on the level were answered correctly.

The first day of the study was a training day to familiarize each subject with the computer, the nature of the practice, and the strategies. In particular, the pictorial and manipulative slide rule strategy needed careful explanation and practice.

Data collection consisted of a detailed record of protocols indicating which strategy was chosen by each subject for each fact on each level. The finger calculating strategy was associated with the analytic mode of operation (Ginsberg, 1977). Frequencies of second tries and accuracy of responses were recorded. Audio-taped protocols were also made of each subject during each session. Data from the protocols were analyzed qualitatively (Kantowski, 1977; Lester & Kerr, 1979; Snow, 1974).

## Results And Discussion

Table 1 shows that all the subjects were highly successful. Eleven subjects scored at least 91% correct on each of the four levels of difficulty. The remaining two, S3 and S13 were at least 78% correct on each level. There were only two levels on which mastery had not been reached, Level 3 by S3 and Level 4 by S13.

Insert Table 1 about here

Insert Table 2 about here

Frequencies of second tries on problems not including those resulting from computer entry errors are shown in Table 2. S3 shows the greatest total of second tries. The rest of the subjects had generally fewer frequencies of second tries and experienced very high success. This was likely due to the time of year the study was conducted. Mastery could be predictably lower if done earlier in the academic year.

Insert Table 3 about here

Table 3 summarizes each subject's performance according to level and strategy. For more visually descriptive reporting, individual line graphs and corresponding stacked bar graphs are presented. The following discussion of the 13 subjects is organized according to those who changed operation (S2, S3, S4, S9, S11, S13); and those who remained in the analytic mode (S1, S10, S12), those who remained in the harmonic mode (S5, S6, S7, S8), and those who remained in the geometric mode (none).

Those Who Changed Modes of Operation

The figures labeled correspondingly for S2, S3, S4, S9, S11, and S13 show that, while responding to addition facts, these children tended toward the manipulative strategy as level of difficulty increased. The line graph for each subject shows any change in choice of strategy; the corresponding stacked bar graph shows any change in choice of mode of operation.

Insert Figures 1-13 about here

S13, for example, began with only 11% use of the concrete strategy on Level 1 and increased to 19% on Level 2, 58% on Level 3 and stabalized with 47% on Level 4. She never chose to use her fingers or the pictorial strategy, available by the push of P on the keyboard. Her behavior was predictable and consistent. Figure 13a shows her change in use of each strategy across levels and Figure 13b shows her change in choice of mode of operation. The stacked bar graph shows darkened horizontal lines marking the geometric mode from the analytic for each level. Observing the position of these bars facilitates discriminating between changing modes of operation and remaining in only one mode of operation. S13 demonstrated a greater and greater use of the geometric mode. She started in Levels 1 and 2 in an analytic mode and moved toward the harmonic in Levels 4 and 5.

Figure 11a shows that S11 exercised a great deal of choice. By the time she reached Levels 3 and 4, she changed considerably toward an increased use of the pictorial strategy. Figure 11b points out an exclusive use of the analytic mode in Levels 1 and 2 and then a complete shift into the geometric by Level 4.

Those Who Remained in One Mode of Operation

Seven of the 13 subjects clearly preferred one mode over the other modes. These were S1, S5, S6, S7, S8, S10, and S12, whose results can be found in the figures labelled correspondingly.

Analytic. Three of these seven, S1, S10, and S12, tended toward the use of the analytical mode of operation. The corresponding figures indicate that even though strategy choices were made, they operated within one mode. For example, S1 and S12 chose between the two analytic modes as seen in the corresponding Figures 1a and 12a. Despite these choices, he and she, respectively, each functioned 100% within the analytic mode throughout all levels of difficulty (see Figures 1b and 12b). S10 most frequently chose between the symbolic and finger strategies and later started to choose pictures. She also started to explore with the manipulative strategy and finger algorithms at the highest level of difficulty. But Figure 10b shows a clear case of preference toward the analytic mode.

Harmonic. The other four of these seven subjects, S5, S6, S7, and S8, operated in a harmonic mode for these exercises. The figures, labelled correspondingly, reveal a general tendency for 25 - 75% use of the analytic modes and 25 - 75 % use of the geometric modes for each level. Even though Figure 6a shows S6 using both geometric mode strategies less frequently as level of difficulty increased, this doesn't seem to suggest strongly enough a trend to change modes (even if it is in the unexpected direction toward the analytic). The stacked bar graph in Figure 6b shows a trend toward the harmonic mode for these problems. On each level the subject chose modes in the 7 - 88% range showing neither a strong analytic nor a geometric operational choice for these problems.

In contrast, a much stronger case for the harmonic operational choice is made with S7. Figure 7b shows all but one level to have elicited choices within the 25 - 75% range. His range is 16 - 55%. That is, at any level

he operated within either the analytic or the geometric modes 16 - 55% of the time (see darkened horizontal bars).

Geometric. No subjects appeared to self-regulate their work on these addition fact exercises into the geometric mode of operation. There are several possible explanations for this. That the manipulative slide rule was not (and could not) be a physical part of the microcomputer might have been a factor. Also, a general lack of manipulative activity in the first graders' mathematics classes, let alone with the particular slide rule used in the study, might be an explanation. An investigation over a longer period of time might help to identify geometric operational choices.

Insert Table 4 about here

Table 4 shows how seldom the children chose the manipulative slide rule strategy. The frequent use of fingers suggests that possibly to restrict the use of fingers (as teachers often do) might bring different results. So this was done.

For this follow-up phase each subject was given five extra randomly generated problems at each of the four levels, this time restricting the use of fingers as a strategy choice. The results for S1, S2, S4, S5, S9, S11, S12, and S13 were the same; whereas, the results for S6, S7, S8, and S10 differed. (S3 was unavailable for this extra session).

Having a sampling of only 20 responses (five per level) for each subject during the follow-up phase makes it risky to draw any conclusions for these exercises. It is suspected that if an entire study were done restricting the use of fingers, the end result for each subject would be similar, thus

supporting the contention (Ginsberg, 1977) that finger algorithms are an analytic approach.

## Conclusion

This study showed extremely successful performance on basic addition exercises by first graders who chose their own strategy to determine a correct response. In addition to this success, each subject demonstrated a pattern or consistency in their choices of strategies. These results suggest the value of providing strategy options during practice exercises for the young student. Teacher-determined uses of symbolic, pictorial, or manipulative strategies might not be most facilitating for all students.

More of this type of research would provide greater understanding of self-regulatory behavior in the learning process and would offer new direction in instructional planning. In particular, there is the need to investigate self-regulatory patterns with older children in more complex problem solving situations. Other further research should investigate the relationship between (a) self-regulation as subject matter increases in difficulty and (b) self-regulation when subject matter difficulty remains constant and understanding increases.

Finally, it was astounding to observe first graders maintaining such long attention spans session after session for an average length of 51 minutes. Though the Hawthorne effect might apply in this study, the role of the microcomputer was undoubtedly an influencing factor. Students were significantly involved.

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TABLE 1

Percentage of Problems Correct by Each Subject

According to Level of Difficulty

| Difficulty Level | Number Of Facts | Subject 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low 1 | 9 | 100 | 100 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 16 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3 | 24 | 96 | 100 | 79 | 100 | 92 | 100 | 100 | 96 | 100 | 100 | 100 | 100 | 96 |
| High 4 | 32 | 91 | 100 | 84 | 100 | 100 | 91 | 100 | 100 | 94 | 100 | 100 | 97 | 78 |

TABLE 2

Frequency of Second Tries Not Due to Entry Errors

by Each Subject According to Level of Difficulty

| Difficulty Level | Number Of Facts | Subject 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low 1 | 9 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| 2 | 16 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 3 | 24 | 1 | 4 | 10 | 0 | 2 | 0 | 0 | 2 | 1 | 0 | 2 | 0 | 3 |
| High 4 | 32 | 7 | 1 | 8 | 2 | 4 | 6 | 1 | 4 | 0 | 1 | 0 | 1 | 5 |

TABLE 3

Percentage of Use of Each Strategy

for Each Subject According to Level

| Difficulty Level | Number Of Facts | Stragegy | Subject 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Low 1 | 9 | Symbolic | 44 | 78 | 33 | 89 | 0 | 56 | 44 | 78 | 78 | 100 | 56 | 67 | 89 |
| | | Finger | 56 | 22 | 44 | 0 | 56 | 0 | 0 | 22 | 11 | 0 | 44 | 33 | 0 |
| | | Pictorial | 0 | 0 | 0 | 0 | 0 | 22 | 33 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Manipulative | 0 | 0 | 22 | 11 | 44 | 22 | 22 | 0 | 11 | 0 | 0 | 0 | 11 |
| 2 | 16 | Symbolic | 31 | 38 | 0 | 100 | 25 | 13 | 63 | 50 | 31 | 100 | 56 | 44 | 81 |
| | | Finger | 69 | 63 | 100 | 0 | 75 | 0 | 0 | 50 | 69 | 0 | 44 | 56 | 0 |
| | | Pictorial | 0 | 0 | 0 | 0 | 0 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Manipulative | 0 | 0 | 0 | 0 | 0 | 38 | 13 | 0 | 0 | 0 | 0 | 0 | 19 |
| 3 | 24 | Symbolic | 4 | 17 | 0 | 21 | 29 | 71 | 67 | 21 | 13 | 92 | 29 | 25 | 50 |
| | | Finger | 96 | 58 | 67 | 79 | 29 | 13 | 17 | 17 | 79 | 0 | 63 | 75 | 0 |
| | | Pictorial | 0 | 21 | 13 | 0 | 0 | 17 | 8 | 54 | 4 | 8 | 0 | 0 | 0 |
| | | Manipulative | 0 | 4 | 21 | 0 | 42 | 0 | 8 | 8 | 4 | 0 | 8 | 0 | 50 |
| High 4 | 32 | Symbolic | 25 | 19 | 13 | 6 | 9 | 63 | 28 | 25 | 3 | 88 | 16 | 19 | 53 |
| | | Finger | 75 | 25 | 28 | 22 | 69 | 13 | 28 | 63 | 3 | 3 | 3 | 81 | 0 |
| | | Pictorial | 0 | 53 | 47 | 44 | 3 | 13 | 38 | 13 | 88 | 6 | 81 | 0 | 0 |
| | | Manipulative | 0 | 3 | 13 | 28 | 19 | 13 | 6 | 0 | 6 | 3 | 0 | 0 | 47 |

## Figure Captions

Figure 1a. Percentage of responses according to strategy for S1.

Figure 1b. Percentage of responses according to mode of operation and strategy for S1.

Figure 2a. Percentage of responses according to strategy for S2.

Figure 2b. Percentage of responses according to mode of operation and strategy for S2.

Figure 3a. Percentage of responses according to strategy for S3.

Figure 3b. Percentage of responses according to mode of operation and strategy for S3.

Figure 4a. Percentage of responses according to strategy for S4.

Figure 4b. Percentage of responses according to mode of operation and strategy for S4.

Figure 5a. Percentage of responses according to strategy for S5.

Figure 5b. Percentage of responses according to mode of operation and strategy for S5.

Figure 6a. Percentage of responses according to strategy for S6.

Figure 6b. Percentage of responses according to mode of operation and strategy for S6.

Figure 7a. Percentage of responses according to strategy for S7.

Figure 7b. Percentage of responses according to mode of operation and strategy for S7.

Figure Captions (cont)

Figure 8a. Percentage of responses according to strategy for S8.

Figure 8b. Percentage of responses according to mode of operation and strategy for S8.

Figure 9a. Percentage of responses according to strategy for S9.

Figure 9b. Percentage of responses according to mode of operation and strategy for S9.

Figure 10a. Percentage of responses according to strategy for S10.

Figure 10b. Percentage of responses according to mode of operation and strategy for S10.

Figure 11a. Percentage of responses according to strategy for S11.

Figure 11b. Percentage of responses according to mode of operation and strategy for S11.

Figure 12a. Percentage of responses according to strategy for S12.

Figure 12b. Percentage of responses according to mode of operation and strategy for S12.

Figure 13a. Percentage of responses according to strategy for S13.

Figure 13b. Percentage of responses according to mode of operation and strategy for S13.

Figure 1a. Percentage of responses according to strategy for S1.



Figure 1b. Percentage of responses according to mode of operation and strategy for S1.

Figure 2a. Percentage of responses according to strategy for S2.



Figure 2b. Percentage of responses according to mode of operation and strategy for S2.

Figure 3a. Percentage of responses according to strategy for S3.



Figure 3b. Percentage of responses according to mode of operation and strategy for S3.

Figure 4a. Percentage of responses according to strategy for S4.



Figure 4b. Percentage of responses according to mode of operation and strategy for S4.

Figure 5a. Percentage of responses according to strategy for S5.



Figure 5b. Percentage of responses according to mode of operation and strategy for S5.

Figure 6a. Percentage of responses according to strategy for S6.



Figure 6b. Percentage of responses according to mode of operation and strategy for S6.

Figure 7a. Percentage of responses according to strategy for S7.



Figure 7b. Percentage of responses according to mode of operation and strategy for S7.

Figure 8a. Percentage of responses according to strategy for S8.



Figure 8b. Percentage of responses according to mode of operation and strategy for S8.

Figure 9a. Percentage of responses according to strategy for S9.



Figure 9b. Percentage of responses according to mode of operation and strategy for S9.

Figure 10a. Percentage of responses according to strategy for S10.



Figure 10b. Percentage of responses according to mode of operation and strategy for S10.

Figure 11a. Percentage of responses according to strategy for S11.



Figure 11b. Percentage of responses according to mode of operation and strategy for S11.

Figure 12a. Percentage of responses according to strategy for S12.



Figure 12b. Percentage of responses according to mode of operation and strategy for S12.

Figure 13a. Percentage of responses according to strategy for S13.



Figure 13b. Percentage of responses according to mode of operation and strategy for S13.

TABLE 4

Percentage of Use of Each Strategy

for All Levels and All Subjects

| Strategies | | | |
|---|---|---|---|
| Symbolic | Finger | Pictorial | Manipulative |
| 38 | 36 | 16 | 10 |